U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Unsaturated Zone Transport

Presented to:
Nuclear Waste Technical Review Board

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June 20-21, 2001
Las Vegas, NV

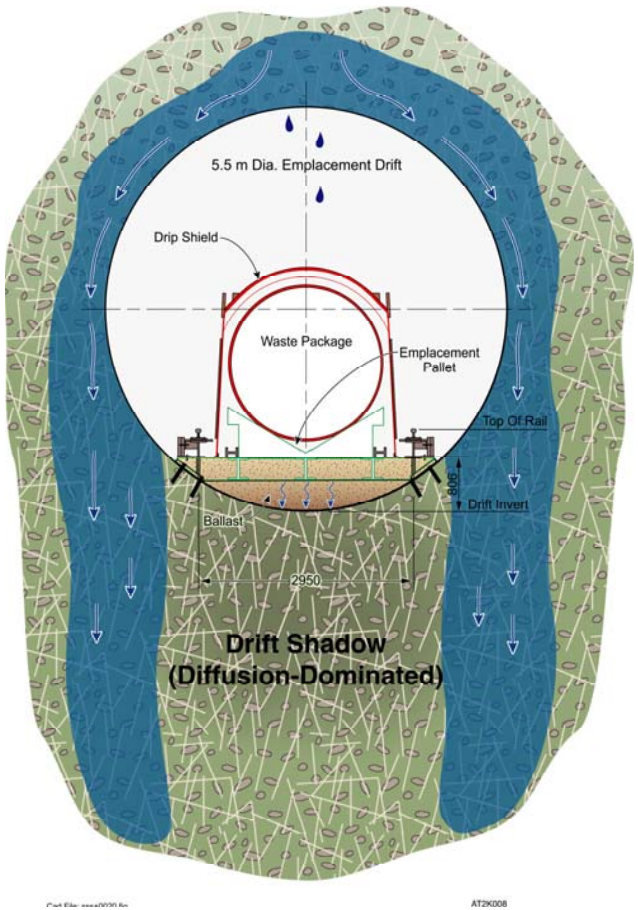
YUCCA MOUNTAIN PROJECT

Introduction

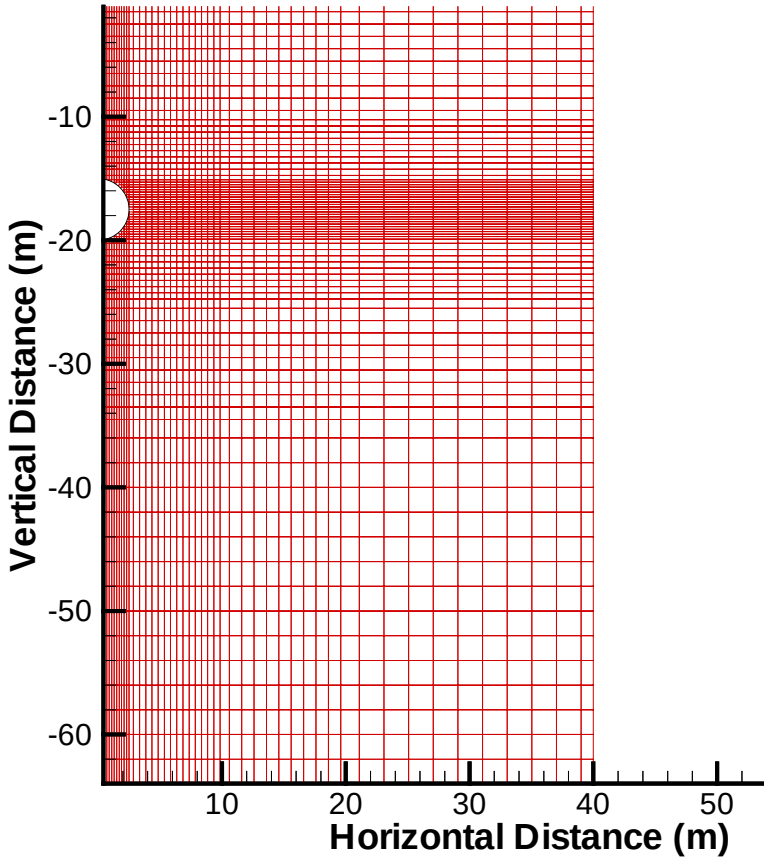
- **Conservatism in Radionuclide Transport**
  - **Drift Shadow**
  - **Radionuclide Transport Calculation Methods**
- **Effects of Thermal Operating Modes**
  - **Expansion of Repository Footprint**
  - **Thermally-Driven Coupled Processes**
- **Multiple Lines of Evidence**

Conservatism in Radionuclide Transport: Drift Shadow

Drift shadow concept



Subsystem model for drift shadow: transport in the tsw35

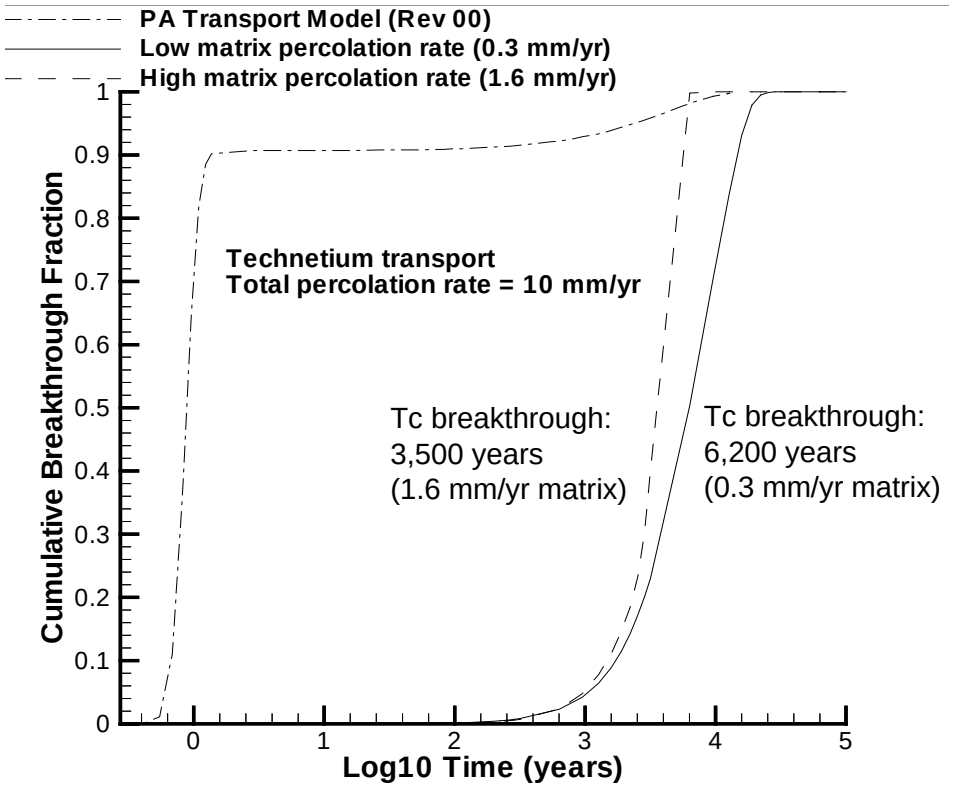


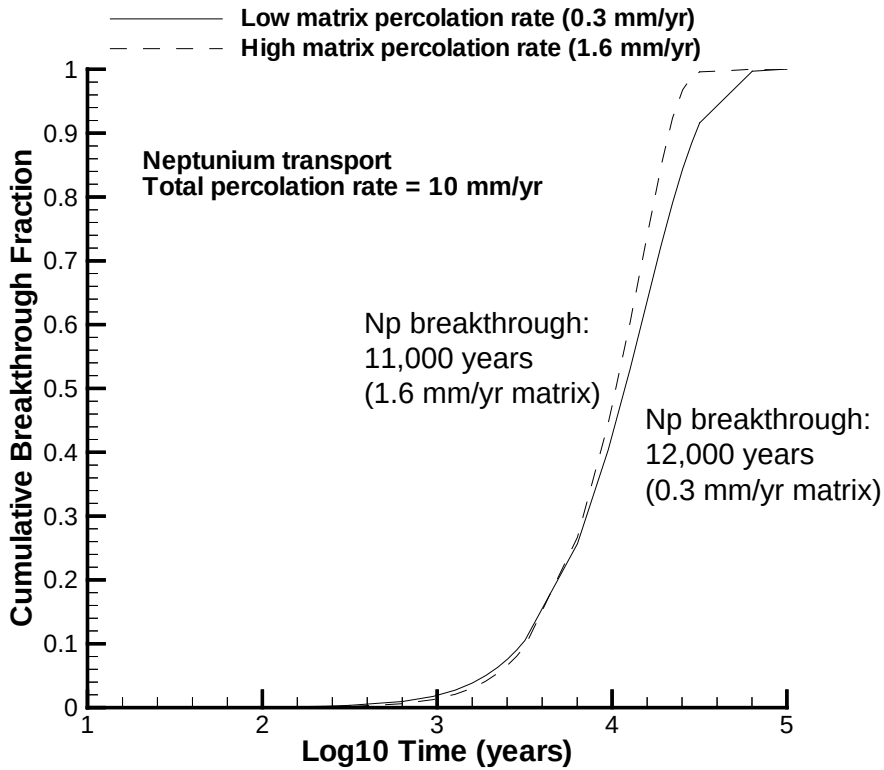
Conservatism in Radionuclide Transport: Drift Shadow

(Continued)

Transport in the drift shadow results in much longer radionuclide transport times than in the baseline transport models

Breakthrough curves at 45 m below potential waste emplacement drift

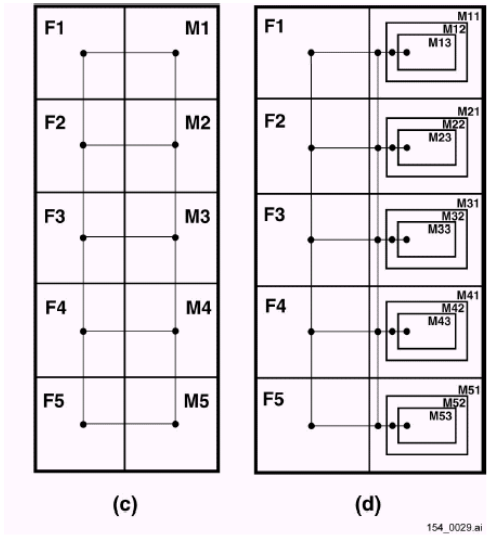




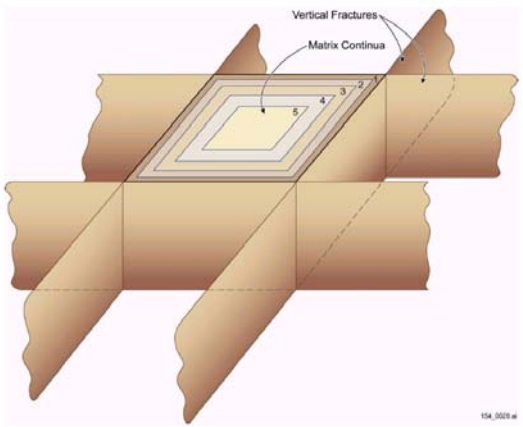
TSPA: partial implementation through advective-diffusive flux splitting in drift

Conservatism in Radionuclide Transport: Radionuclide Transport Calculation Methods

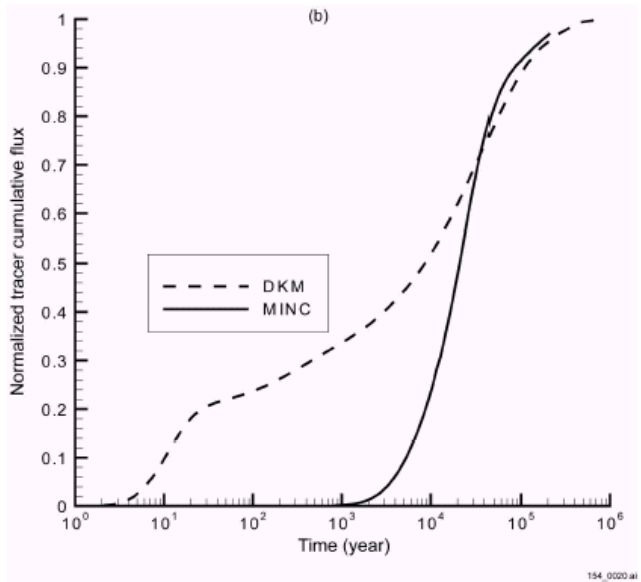
Schematic Diagram of a One-Dimensional Column of Gridblocks and Two Models of Flow



Baseline DKM process models for UZ transport predict earlier breakthrough compared to MINC approach



Matrix Discretization for the Multiple Interacting Continua Model Scheme

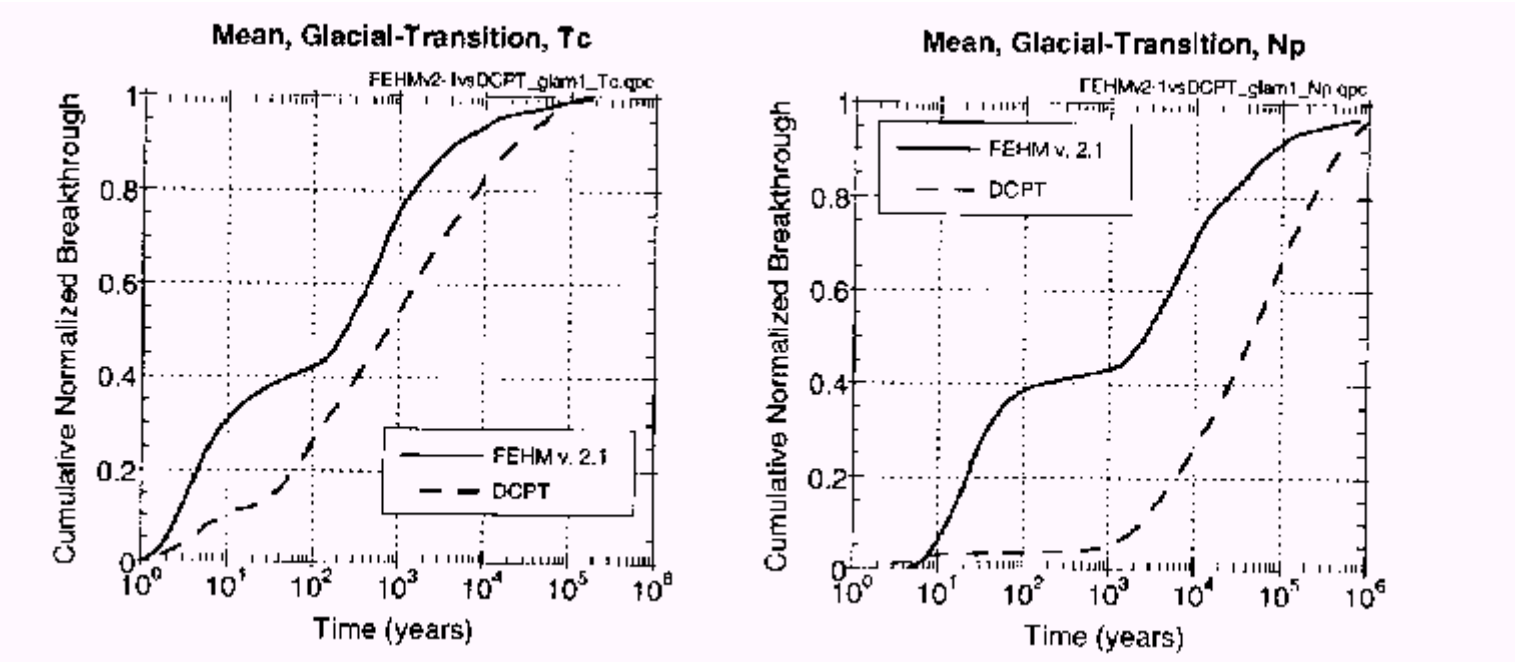


Normalized Tracer Cumulative Flux at Water Table as a Function of Time

Conservatism in Radionuclide Transport: PA Model for UZ Transport

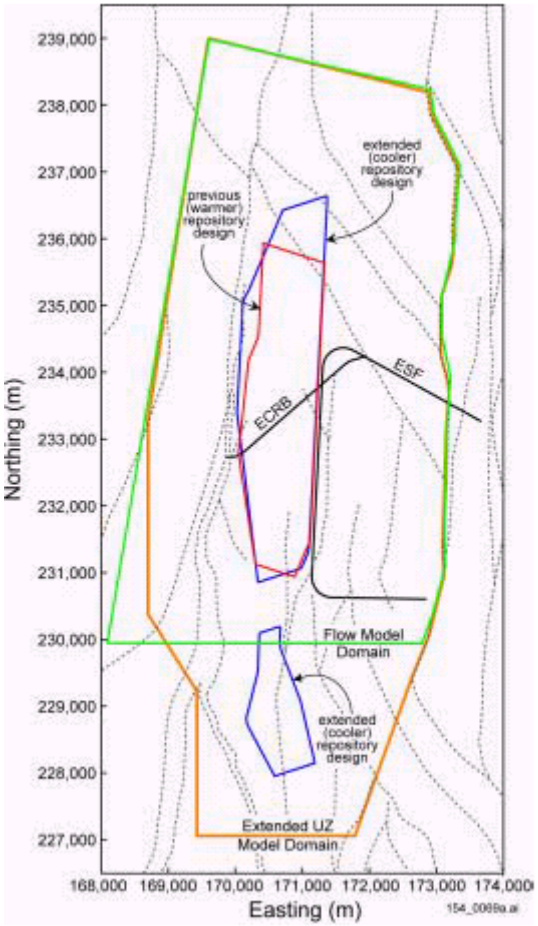
Performance Assessment model is found to give earlier breakthrough than process models

Comparison of cumulative normalized breakthrough curves at the water table using FEHM V2.1 and DCPT V1.0 for the mean infiltration, glacial transition climate



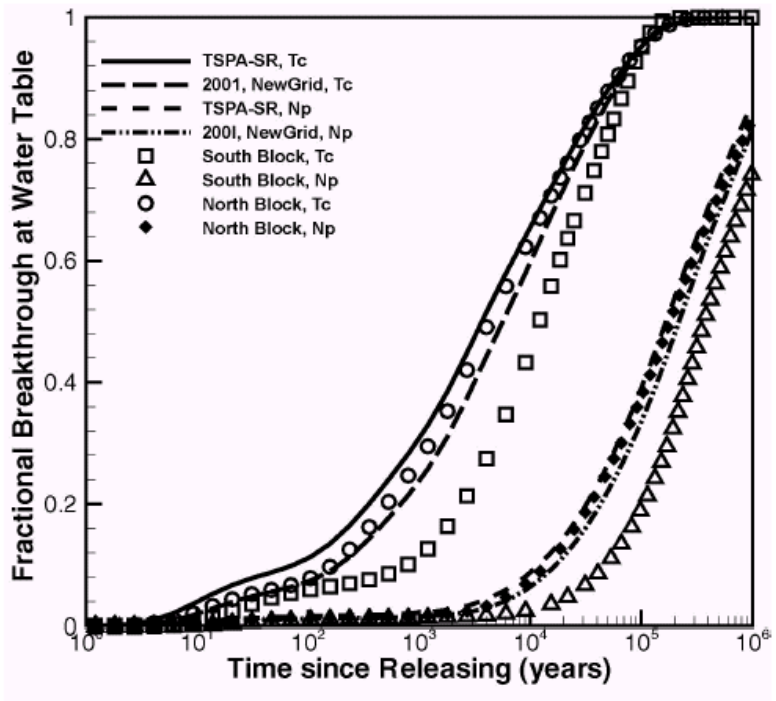
TSPA: more realistic transport method not yet implemented

Thermal Operating Modes: Expansion of Repository Footprint



Plan View of Unsaturated Zone Model Domains and Potential Repository Layouts

Breakthrough curves for the southern extension show longer transport times to the water table than for the baseline potential repository footprint, but overall effect is small. TSPA: expanded footprint not included.



Simulated Breakthrough Curves of Cumulative Tracer and Radionuclide Mass Arriving at the Water Table

Thermal Operating Modes: Thermal-Hydrologic Effects

- **Thermal-Hydrologic (TH) Effects – Mountain Scale**
  - **Mountain-scale flow beneath potential repository dominated by climate change after 600 years for high and low temperature operating modes. TH processes expected to have limited influence on mountain-scale radionuclide transport**
  - **Expected effects are negligible, not included in TSPA**
- **TH Effects – Drift Scale**
  - **High-temperature operating mode: Local dryout of fractures and matrix (2500 to 3000 years) will prevent transport until rock re-wetting occurs**
  - **Low-temperature operating mode: Local dryout of fractures will prevent releases to the fractures for approximately 2000 years. Matrix water is retained**
  - **Not included in TSPA but may result in improved performance**

Thermal Operating Modes: THC and THM Effects

- **Thermal-Hydrologic-Chemical (THC) Effects**
  - **Estimated changes in fracture permeability due to THC processes are less than one order of magnitude. This is much smaller than natural variability of fracture permeability. Therefore, THC processes are expected to have limited influence on transport**
  - **Expected effects are negligible, not included in TSPA**
- **Thermal-Hydrologic-Mechanical (THM) Effects**
  - **Estimate changes in fracture permeability about 10 to 40%. This is much smaller than natural variability of fracture permeability. Therefore, THM processes are expected to have limited influence on transport**
  - **Expected effects are negligible, not included in TSPA**

Multiple Lines of Evidence

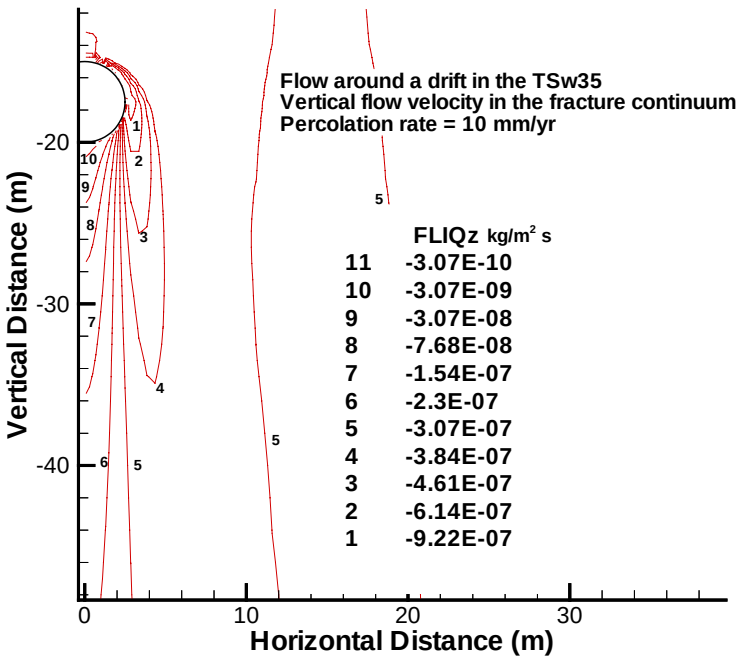
- **Fracture-matrix interaction**
  - **Hydrologic observations that matrix remains unsaturated despite large percolation flux**
  - **Observations of geochemical disequilibrium between perched water and matrix pore water**
  - **Steep gradients for uranium between fractures and matrix at Nopal I unsaturated zone site, Pena Blanca**
- **Long transport times**
  - **Low mobility of uranium in the unsaturated zone at Pena Blanca over 100,000 year time frame**
  - **Limited migration (45 cm) of copper and lead in the unsaturated zone at Akrotiri, Santorini over 3600 years**

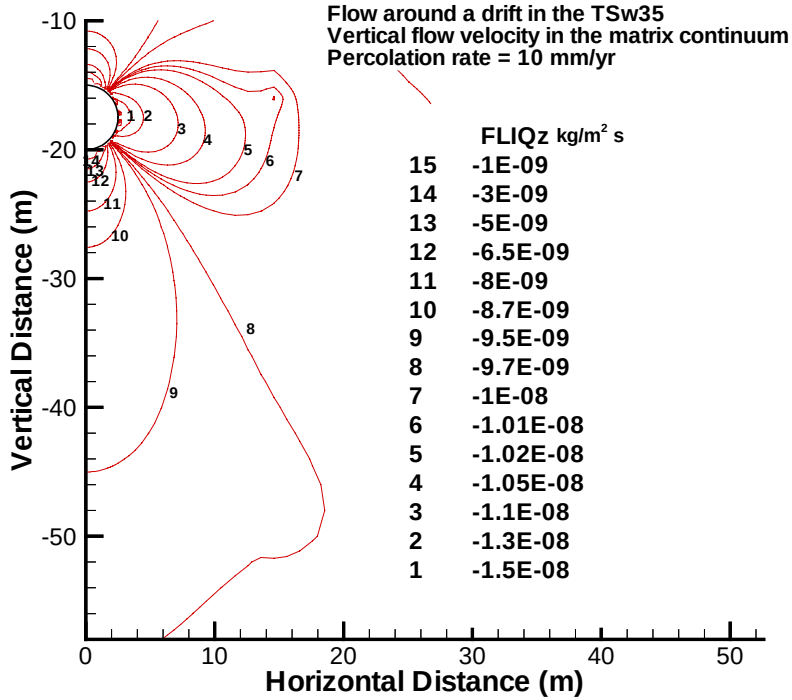
Summary

- **Transport times in the drift shadow are orders of magnitude longer than predicted by the existing PA model. The transport times in the drift shadow model are significant relative to the 10,000 year regulatory time frame**
- **Process model representation of matrix diffusion is conservative due to matrix discretization effects, resulting in shorter predicted breakthrough times. The PA model is conservative relative to the process models over most of the breakthrough curve**
- **Including the southern extension to the potential repository block results in slightly longer transport times to the water table**
- **Local dryout from TH processes will delay or reduce radionuclide transport immediately beneath potential waste emplacement drifts for 2000 to 3000 years. Other thermally-driven coupled process effects are expected to have minimal effects on transport**

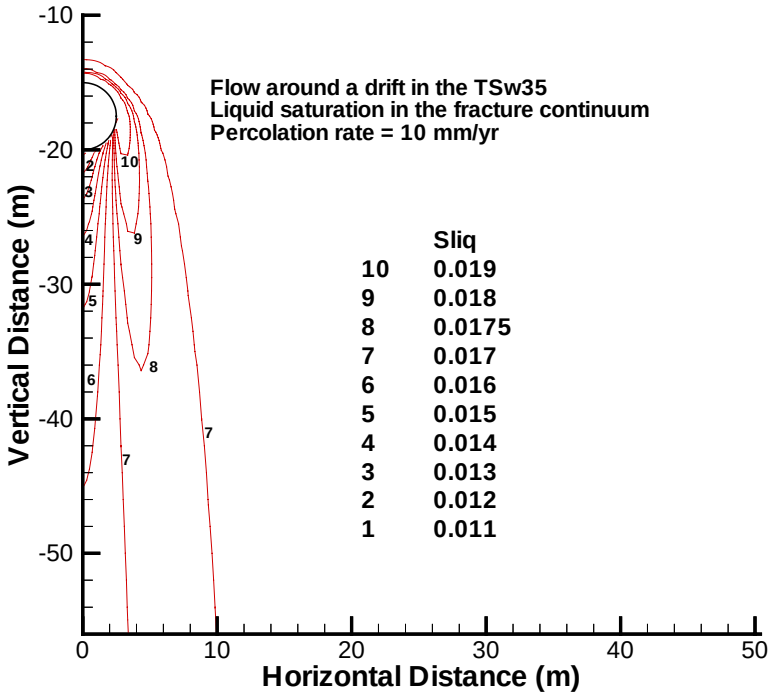
Backup

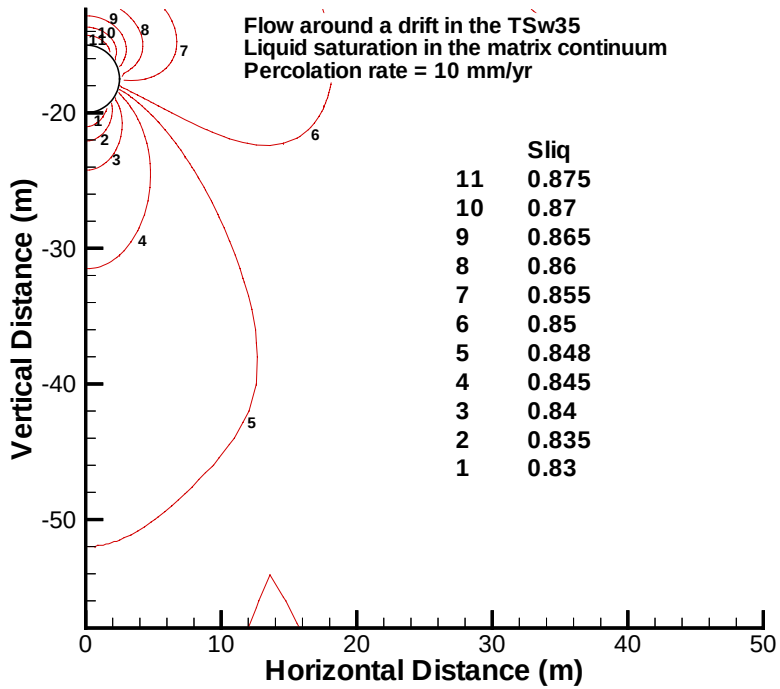
Drift Shadow: Unsaturated Flow



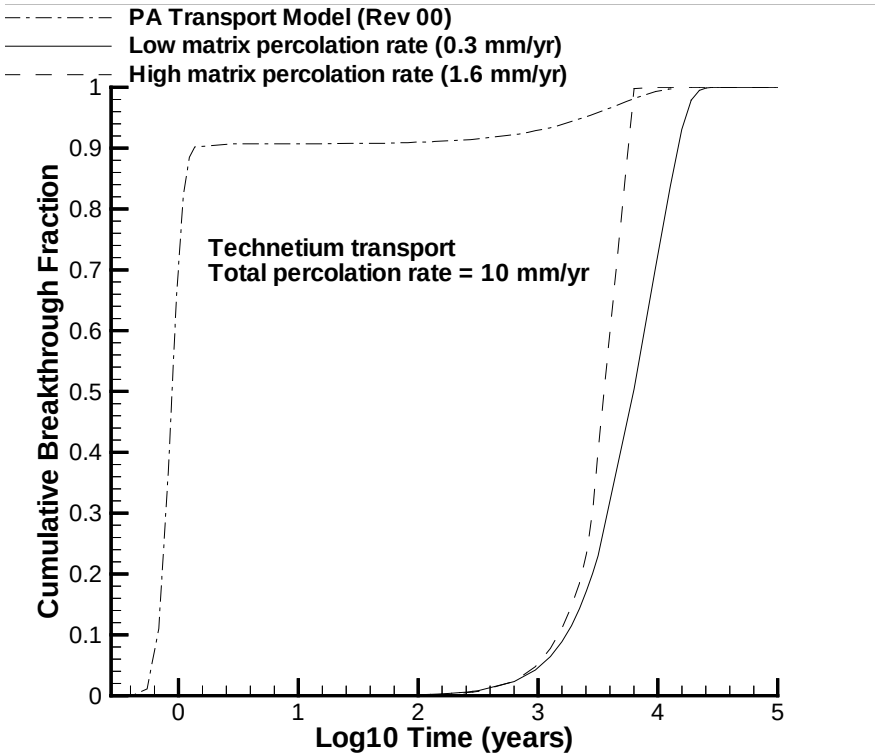


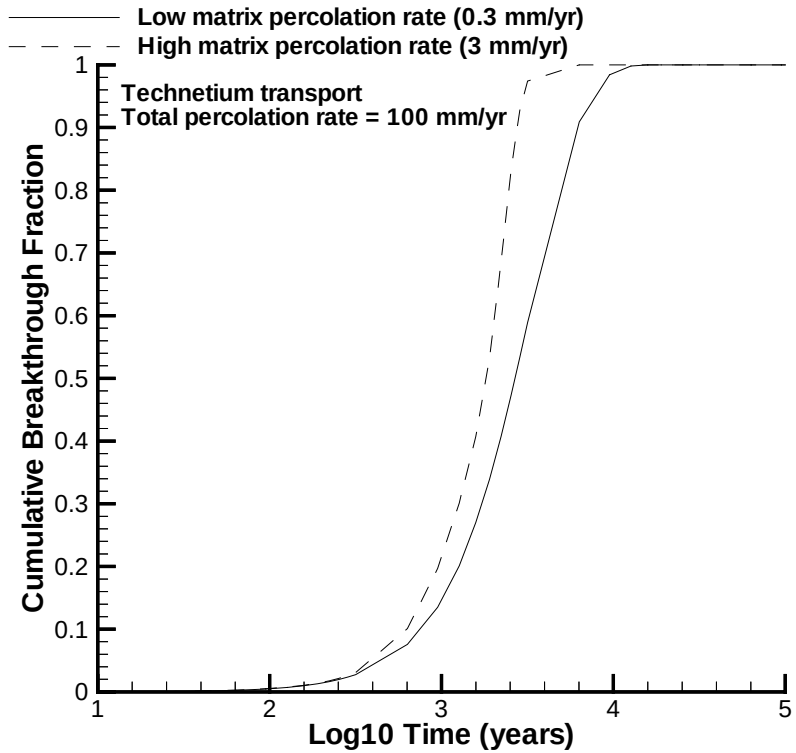
Drift Shadow: Unsaturated Flow



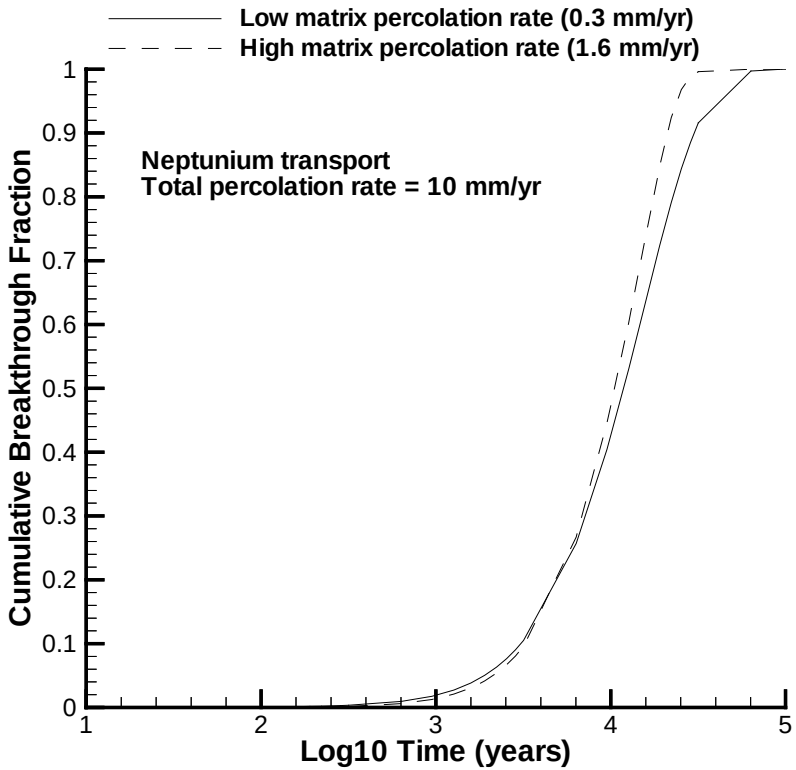


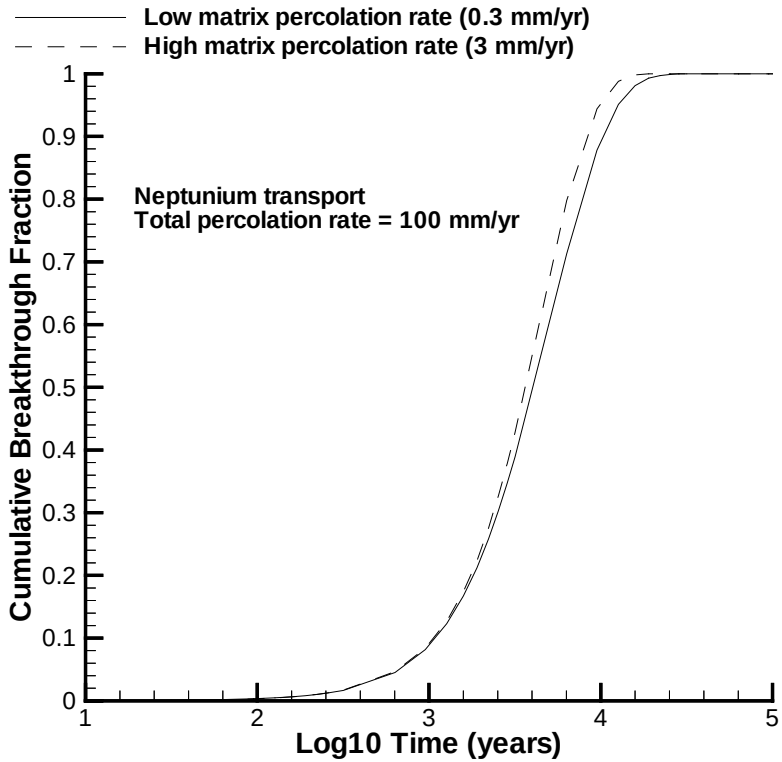
Drift Shadow: Technetium Transport



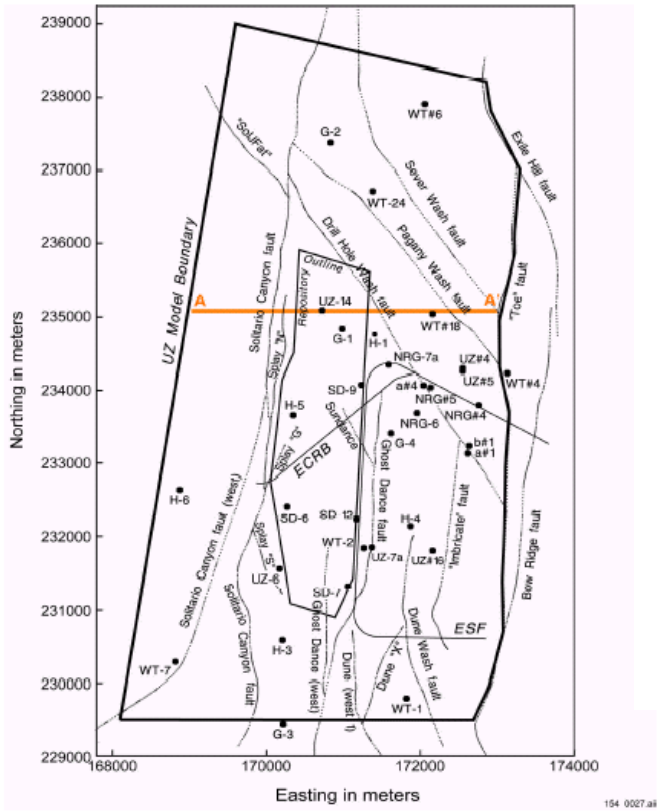


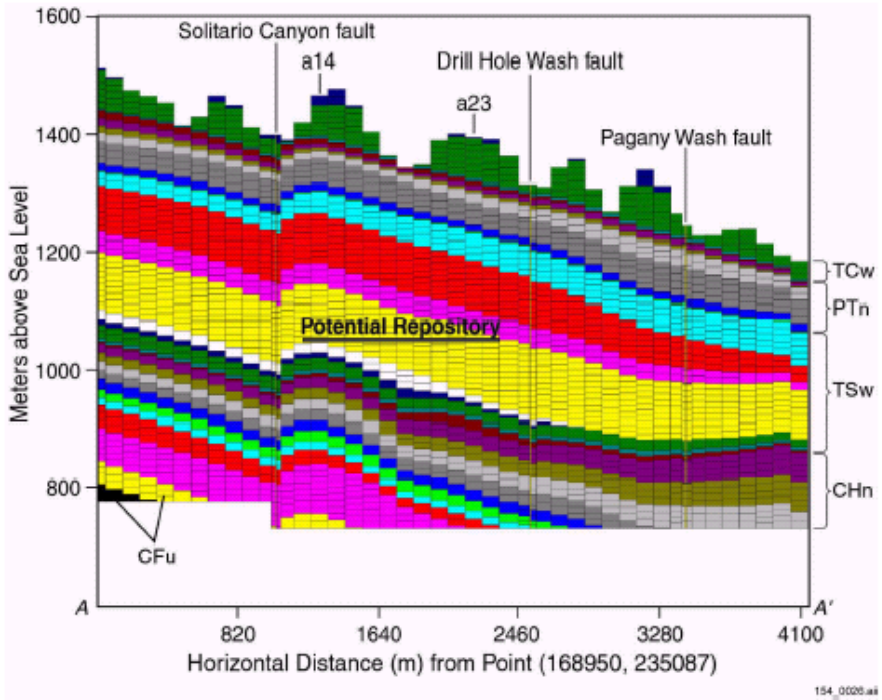
Drift Shadow: Neptunium Transport



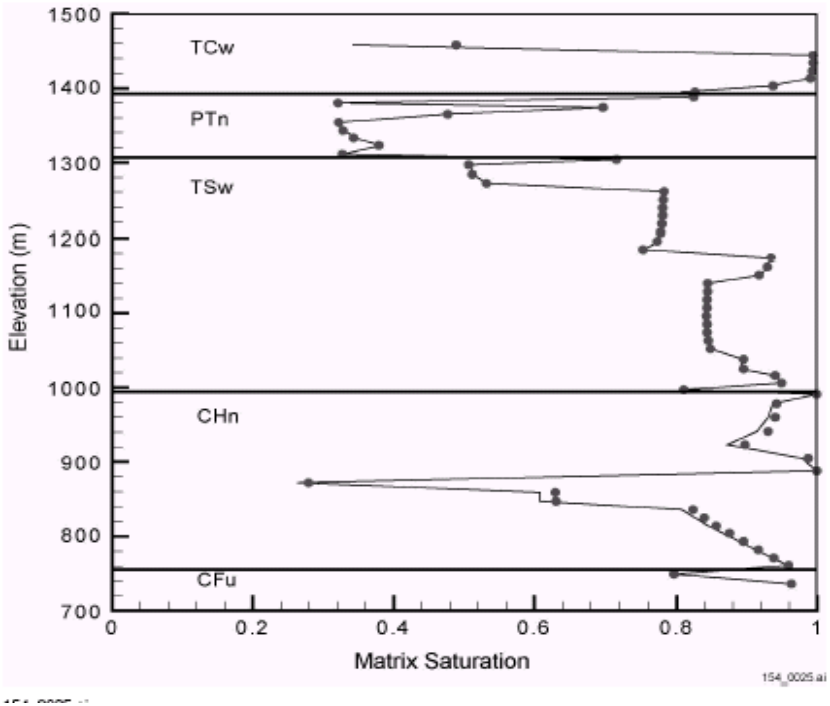


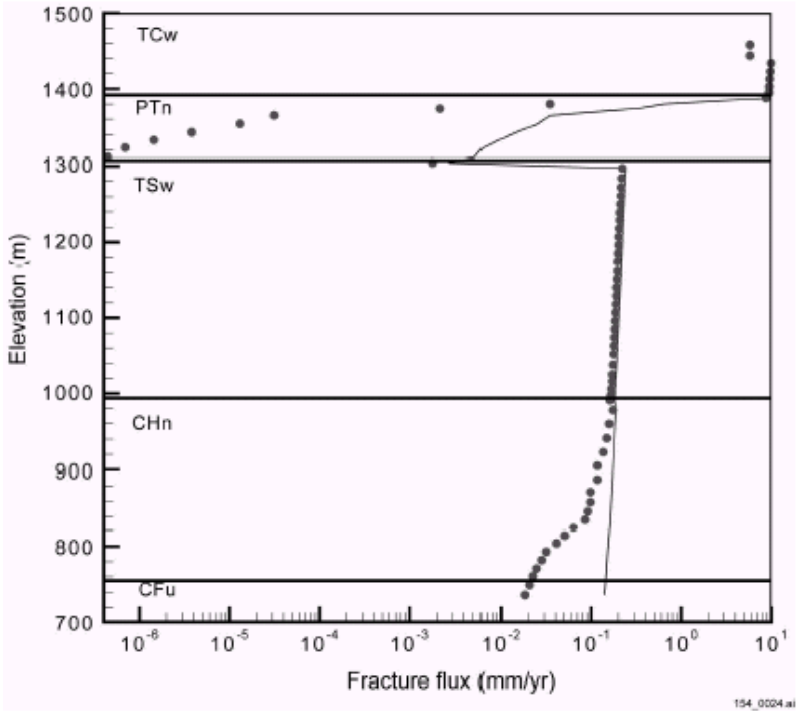
Matrix Block Discretization



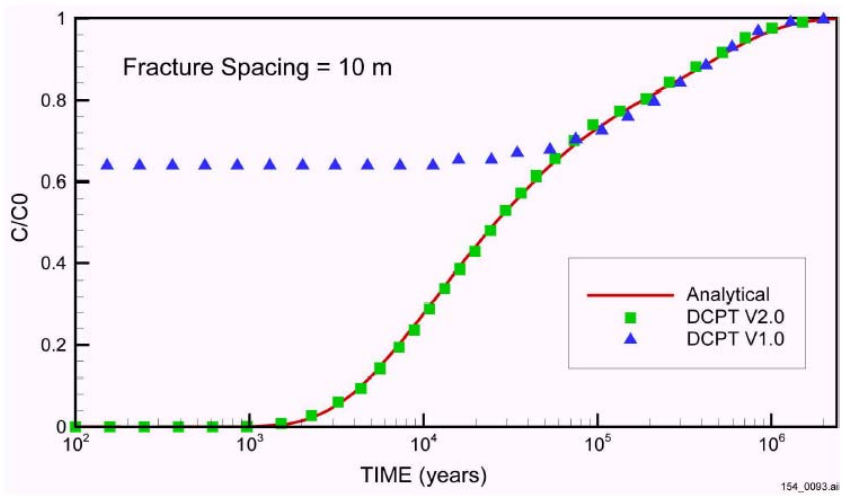


Matrix Block Discretization: Flow





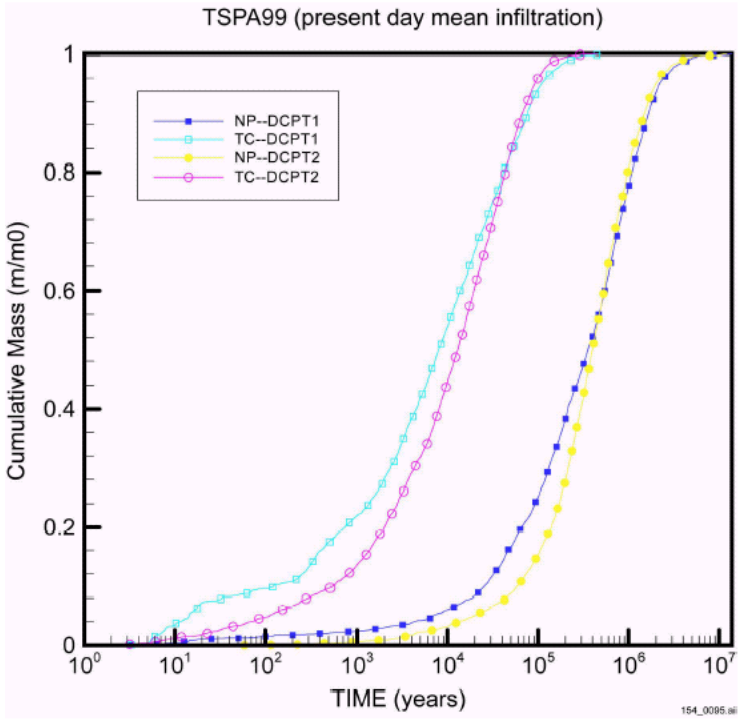
Radionuclide Transport Calculation Methods: Results



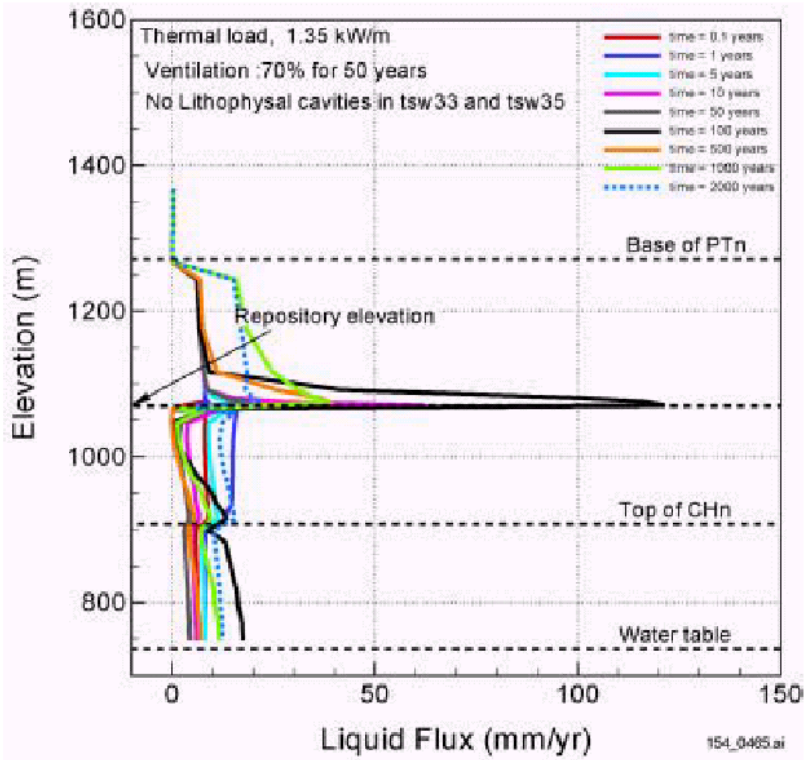
154_0093.ai

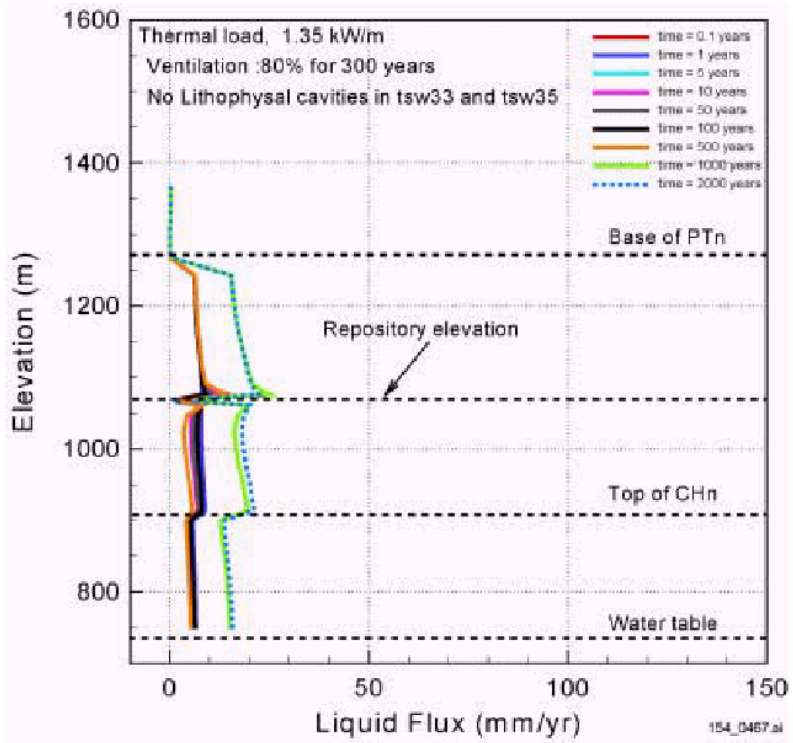
DTN: LB0401AMRU0185.014

NOTE: The current model is DCPT v1.0 (LBNL (1999 [132448]); DCPT v2.0 is a more-refined version. C is the concentration of tracer, and CO is the concentration at inlet.



Thermal Operating Modes: TH Coupled Processes – Mountain Scale





Thermal Operating Modes: TH Coupled Processes – Drift Scale